LETTERS TO THE EDITORS

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Production of Mesons by Electrons

IN view of recent developments in the design of accelerators for the production of high-energy electrons, it is desirable to investigate the probability of producing mesons by electron bombardment.

(1) The simplest process of this type is:

The production of mesons in this way bears a close resemblance to the production of quanta in radiation processes. It results from the mutual interaction of electrons and protons with the radiation field and the meson field. In analogy with radiation processes, we can decompose this process into two elementary processes, the first of which corresponds to the electrostatic scattering of the electron by the proton, and the second of which leads to the production of a meson:

It should be noted that from the point of view of perturbation theory the first of these processes is a second-order process. It is found that so long as we restrict ourselves to energies for which the proton recoil is negligible (that is, to energies small compared with 940 MeV.) we may neglect the effect of retardation, which would appear in the representation of the electric scattering as the emission and absorption of light-quanta by electron and proton. With this restriction we may also neglect the small interaction terms of Yukawa's theory.

The total cross-section for the production of a vector-meson comes out to be

$$\frac{3}{\pi} \left(\frac{1}{137} \right)^2 \frac{g^2}{\hbar c} \lambda_0^2 I(E),$$

where λ_0 is the Compton wave-length of the meson; g is the interaction constant of the Yukawa theory ('meson-charge'); E is the energy of the electron with the rest-mass of the meson as a unit; and $I(E)$ is given by

$\frac{E}{I(E)}$	1.25	1.5	2.0	4.0	10
	2.4	21	200	2000	(7400)

The last figure is put in brackets because the energy to which it belongs is outside the region in which the proton recoil is negligible.

For electrons of energy ~ 300 MeV., this gives a cross-section of the order 10^{-33} cm.².

(2) Another possible process is

Decomposing this process into elementary processes, we have to consider that the neutron first emits a negative meson and that the electron is then scattered inelastically by the resulting proton. The result is the same as under (1); but a small correction factor (> 1) due to the electrostatic interaction between the meson and the proton has to be added.

(3) These cross-sections are so small that it is worth while considering whether or not larger cross-sections can be obtained by bombarding nuclei other than hydrogen by electrons. By analogy with *Bremsstrahlung* we might expect the cross-section for an atom with charge Z to be larger by a factor Z . It

turns out that this factor is approximately correct, but its establishment by this analogy is incorrect, since for any nucleus a competing intermediate state occurs:

Neglecting recoil, the energy denominators in the two branches of the process are equal but opposite in sign; the matrix elements corresponding to the Coulomb scattering of the electron differ only in that in the second branch the electron is scattered by the nuclear charge $Z-1$, whereas in the first branch it is scattered by the charge Z . However, since the nucleus $(Z-1)$ can be left in a large number of excited states, the energies of which differ only by small amounts (compared with the meson mass), we obtain a factor of the order:

$$\begin{array}{ll} AZ & \text{for positive mesons} \\ A(A-Z) & \text{for negative mesons,} \end{array}$$

which, multiplying the cross-sections for proton- and neutron-cases respectively, gives the cross-sections for the nuclear process. Furthermore, in the case of heavy atoms and moderate meson energies a Gamow factor expressing the effect of the nuclear charge on the mesons has to be taken into account. This factor favours the production of negative rather than positive mesons.

In the case of heavy nuclei, the factor multiplying the one-particle cross-section may be of the order 10^4 , so that the cross-section for the production of mesons by the bombardment of a heavy nucleus with 300-MeV. electrons is of the order 10^{-29} cm.².

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Oct. 7.

Decay of Holmium-166

WHEN the element holmium is irradiated with slow neutrons the radioactive isotope holmium-166 is produced. This decays by β -emission to the stable isotope of erbium, Er^{166} .

The decay of holmium-166 has been investigated by several observers, the most recent work being that of Bothe¹, who gave the value of 27.3 ± 0.5 hr. for the half life-time; and, using absorption methods,

Fig. 1